Expanded Groundwater Monitoring

For Nonpoint Source Pollution Assessment

In the Salt and Licking River Basins:

Final Report

By

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EXECUTIVE SUMMARY

In order to conduct a more adequate assessment of groundwater resources in the Salt and Licking River basins, Kentucky Watershed Basin Management Unit Number 2 (BMU 2), the Groundwater Branch of the Kentucky Division of Water (KDOW) collected 120 raw-water samples at 37 wells and springs in BMU 2. Sites selected represented ambient groundwater conditions and the various hydrogeologic flow regimes found in the basin. Samples were analyzed for pesticides (including the most commonly used herbicides), total and dissolved metals, nutrients, major inorganic ions, residues and volatile organic compounds, including trichloroethylene (TCE), benzene, toluene, ethylbenzene, xylenes and methyl-tert-butyl ether (MTBE). Additionally, data from 33 other ambient groundwater monitoring sites were data analyzed for this project. The Division of Water sampled these other sites for various other projects, most commonly, the Division's Ambient Groundwater Monitoring Program.

Ambient groundwater quality in BMU 2 is generally good, with land-use the primary determining factor. At some sites, naturally occurring constituents, including iron and manganese, impair groundwater quality. Additional naturally occurring constituents that may also impact groundwater include nitrate-nitrogen, ammonia, total phosphorus and ortho-phosphate. Because these nutrients occur both naturally and through anthropogenic activity, the impact of man's contribution to naturally occurring groundwater chemistry is difficult to assess.

Constituents not naturally occurring that have impacted groundwater in BMU 2 are several common agricultural herbicides, including atrazine and metolachlor and volatile organic compounds, including benzene and MTBE. In BMU 2, the occurrence of herbicides is the result of nonpoint source pollution. The occurrence of volatile organic compounds occurs via point source releases or from nonpoint sources such as urban storm-water runoff.

INTRODUCTION and BACKGROUND

The Kentucky Division of Water (DOW) has adopted an integrated approach to the management of water resources. The approach, known as the Kentucky Watershed Framework, is ". . . a means for coordinating and integrating the programs, tools and resources of stakeholders to better protect, maintain and restore the ecological composition, structure and function of watersheds and to support the sustainable uses of watersheds for the people of the Commonwealth" (KDOW, 2002a). Under this system, the watersheds of the state are sub-divided into five Basin Management Units (BMUs). As part of the data gathering and assessment efforts of the watershed approach, the Division of Water-Groundwater Branch assessed nonpoint source pollution impacts to groundwater within the Salt and Licking River basins (BMU 2).

Before 1995, ambient groundwater quality data throughout the state was inadequate to assess groundwater quality on a regional, basin-wide or statewide scale. In order to correct this situation, the Division of Water initiated statewide ambient groundwater monitoring in 1995 to begin the long-term, systematic evaluation of groundwater quality throughout the state. In 1998, legislation established the Kentucky Interagency Groundwater Monitoring Network, which formalized groundwater assessment efforts. Oversight for this network is through the Interagency Technical Advisory Committee on Groundwater, which includes the Division of Water.

The Division of Water regularly collects ambient groundwater samples throughout the state. To date, the division has collected more than 2000 samples from approximately 330 sites. The information from these samples is used for a variety of purposes, including: 1) assessment and characterization of local and regional baseline groundwater quality, 2) documentation of spatial and temporal variations in groundwater quality 3) support of public water systems, especially through source water characterization and Wellhead Protection, 4) development of Total Maximum Daily Loads (TMDLs) for surface water in areas where groundwater directly influences this resource, 5) support of the state's pesticide management plan, 6) development of groundwater quality standards and aquifer classification and 7) to address compliance and nonpoint source issues. The Division of Water forwards analytical data to the Kentucky Geological Survey (KGS) Ground-Water Data Repository where it is available to the public. Data requests can be made via their website (http://kgs.edu/KGS/home.htm), by phone at (859) 257-5500, or by mail at 228 Mining and Minerals Resources Building, University of Kentucky, Lexington, KY 40506-0107.

Project Description

This project provides additional groundwater quality data in areas lacking adequate information. The objective of this project was to sample 30 groundwater sites in BMU 2 on a quarterly basis for one year, beginning in April 1999. However, because drought affected some low-flow springs, alternate sites had to be selected; therefore, 37 sites were eventually included to meet this grant commitment (Appendix D, Table 1). In addition, data from 33 other sites sampled for various other ambient monitoring efforts from 1993 through 2001 are also included in this report. The Groundwater Branch selected wells and springs to provide good geographical representation of the diverse physiographic and hydrogeologic characteristics and dominant land uses in BMU 2. Samples were analyzed for numerous parameters including nutrients, pesticides, total/dissolved metals, residues, major inorganic ions and volatile organic compounds, as shown in Table 1. Data were compared to various existing standards and to data from unimpacted ("pristine") reference springs (Table 2) to determine possible nonpoint source pollution impacts or other water quality problems, as well as to identify outstanding resources.

Previous Investigations

Comprehensive discussions of groundwater quality within the Salt and Licking River basins were not found in the literature. Faust and others (1980) compiled groundwater quality data on a limited number of parameters for the entire state, but did not analyze or summarize the data. The United States Geological Survey has prepared Hydrologic Atlases (HAs) and 7.5 minute Geological Quadrangle maps

Table 1. Parameters and Standards for Comparison

Parameter	*Standard*	*Source/Discussion* *
Hydroparameters		
Conductivity	800 μmho	No MCL, SMCL, or HAL; this roughly corresponds to 500 mg/L TDS, which is the SMCL
Hardness (Ca/Mg)	0-17 mg/L = soft 17-120 mg/L = moderate > 120 mg/L = hard	No MCL, SCML, or HAL; scale modified from USDA
PH	6.5 to 8.5 pH units	SMCL
Inorganics		
Chloride	250 mg/L	SMCL
Fluoride	4 mg/L	MCL
Sulfate	250 mg/L	SMCL
Metals		
Arsenic	.010 mg/L	MCL
Barium	2 mg/L	MCL
Iron	.3 mg/L	SMCL
Manganese	.05 mg/L	SMCL
Mercury	.002 mg/L	MCL
Nutrients		
Ammonia	.110 mg/L	DEP
Nitrate-n	10 mg/L	MCL
Nitrite-n	1 mg/L	MCL
Orthophosphate	.04 mg/L	No MCL, SMCL, or HAL; Texas surface water standard
Total phosphorous	.1 mg/L	No MCL, SMCL, or HAL; level recommended by USGS NAWQA Program
Pesticides		
Alachlor	.002 mg/L	MCL
Atrazine	.003 mg/L (0.00067 mg/L)	MCL (DEP)
Cyanazine	.001 mg/L	HAL
Metolachlor	.1 mg/L	HAL
Simazine	.004 mg/L	MCL
Residues		
Total Dissolved Solids	500 mg/L	SMCL
Total Suspended Solids	35 mg/L	No MCL, SMCL, or HAL; KPDES permit requirement for sewage treatment plants
Volatile Organic Compounds		
Benzene	.005 mg/L	MCL
Ethylbenzene	.7 mg/L	MCL
Toluene	1 mg/L	MCL
Xylenes	10 mg/L	MCL
MTBE	.050 mg/L	DEP

* Abbreviations:

MCL = Maximum Contaminant Level
SMCL = Secondary Maximum Contaminant Level
HAL = Health Advisory Level
KPDES = Kentucky Pollutant Discharge Elimination System
NAWQA = National Water-Quality Assessment Program (USGS)
DEP = Kentucky Department for Environment Protection risk-based number
USDA = United States Department of Agriculture

Table 2. Reference Springs Analytical Data Summary (Cameron Spring/Lewis County; Nada Spring/Powell County; F. Mullin Spring/Rockcastle County), mg/L.

NPS REFERENCE SITES SUMMARY STATISTICS						
	START DATE	END DATE	NUMBER OF SAMPLES	MEDIAN	MIN	MAX
Conductivity	04/27/95	10/04/00	48	111.25	46.0	448.0
Hardness	07/14/95	12/03/01	28	52.3015	14.039	140.29
pH	04/27/95	10/04/00	44	7.31	6.01	8.12
Chloride	04/27/95	03/07/00	19	1.9	0.6	16.7
Fluoride	04/27/95	03/07/00	33	0.05	< 0.023	0.253
Sulfate	04/27/95	03/07/00	36	7.425	< 5.0	69.4
Arsenic	06/03/98	12/03/01	34	0.002	< 0.002	0.0045
Barium	06/03/98	12/03/01	34	0.0305	0.0040	0.073
Iron	07/14/95	12/03/01	34	0.056	< 0.001	0.337
Manganese	06/03/98	12/03/01	34	0.0035	< 0.001	0.208
Mercury	06/03/98	12/03/01	34	0.00005	< 0.00005	< 0.00005
Ammonia	04/27/95	10/04/00	42	0.02	< 0.02	0.11
Nitrate-n	04/27/95	03/07/00	36	0.1805	< 0.01	0.888
Nitrite-n	04/27/95	03/07/00	21	0.005	< 0.002	0.006
Orthophosphate	04/27/95	10/04/00	43	0.011	< 0.003	0.069
Total Phosphorus	04/27/95	03/07/00	19	0.019	< 0.005	0.019
Alachlor	04/27/95	12/03/01	55	0.00004	< 0.00002	< 0.00006
Atrazine	04/27/95	12/03/01	55	0.00004	< 0.00004	< 0.0003
Cyanazine	05/03/95	12/03/01	48	0.00004	< 0.00004	< 0.0001
Metolachlor	04/27/95	12/03/01	55	0.00004	< 0.00004	< 0.0002
Simazine	04/27/95	12/03/01	52	0.00004	< 0.00004	< 0.0003
TDS	04/27/95	10/04/00	48	63.0	< 10.0	266.0
TSS	04/27/95	10/04/00	48	3.0	< 1.0	13.0
Benzene	04/12/00	12/03/01	20	< 0.0005	< 0.0005	< 0.0005
Ethylbenzene	04/12/00	12/03/01	20	< 0.0005	< 0.0005	< 0.0005
Toluene	04/12/00	12/03/01	20	< 0.0005	< 0.0005	< 0.0005
Xylenes	04/12/00	12/03/01	20	< 0.0005	< 0.0005	< 0.0005
MTBE	04/12/00	12/03/01	20	< 0.001	< 0.001	< 0.001

(GQs) for the entire state. The Kentucky Geological Survey (1969, 2002) has indexed these publications. Geochemical data in the HAs is limited and generally includes only common metals and major inorganic ions. However, the atlases usually provide information that is somewhat more detailed for areas including the Ohio River alluvium. In general, groundwater found in the Ohio River alluvium is hard and may contain high amounts of iron, especially from areas adjacent to valley walls.

Several investigators have mapped karst groundwater basins within BMU 2 and Currens and others (1998, 2002) have compiled the results. Carey and Stickney (2001) have prepared county groundwater resource reports, including general descriptions of groundwater quality. Ray and others (1994) have interpreted groundwater sensitivity to contamination for the entire state. Carey and others (1993) examined data from 4,859 samples collected throughout the state for ammonia, nitrate-nitrogen, nitrite-nitrogen, chloride, sulfate, conductivity, alachlor and triazine. For three important nonpoint source parameters, they found: 1) 4.6% of the samples for nitrate-n exceeded the Maximum Contaminant Level (MCL) of 10.0 mg/L, 2) 0.9% exceeded the MCL of 0.002 mg/L for alachlor and 3) 0.3% exceeded the atrazine MCL of 0.003 mg/L. (Note that this study measured total triazines and did not differentiate between various triazine herbicides, including atrazine, simazine and cyanazine. Additionally, this study applied, perhaps inappropriately, the MCL for atrazine for the entire triazine group.)

Conrad and others (1999) described the occurrence of nitrate-n and fluoride in the state and Fisher (2002) described the occurrence of arsenic. In their study of nitrate-n, Conrad and others (1999) found that MCL exceedances decreased with well depth and that for fluoride less than 1% of 2,363 analyses exceeded the MCL of 2.0 mg/L. Fisher (2002) concludes that "arsenic in Kentucky groundwater generally does not exceed the MCL and there are no widespread occurrences of high arsenic concentrations."

Currens (1979) compiled a bibliography of karst publications for the state and several researchers, including Kipp and Dinger (1991) and Minns (1993) have studied groundwater in eastern Kentucky. These studies, and others, have found that groundwater in eastern Kentucky is generally hard and that naturally occurring water quality problems commonly include iron, manganese, sodium chloride and sulfate. Keagy and others (1993) conducted some smaller scale studies in the Licking River watershed and Keagy found that pesticide concentrations in an epikarst area of the Inner Bluegrass peaked about two weeks after application and then rapidly decreased, indicative of the quick flow nature of karst.

PHYSIOGRAPHIC and HYDROGEOLOGIC SETTING

BMU 2 covers more than 9,000 square miles and includes the Salt and Licking River basins, as well as several other direct Ohio River tributaries. For the purposes of this report, the terms "Licking River Basin" or "Salt River Basin" will also include those adjacent areas that drain directly to the Ohio River. Figure 1 illustrates the location of BMU 2 and the sites included in this study.

Licking River Basin

The Licking River rises in Magoffin County within the Eastern Coal Field physiographic region. The river flows northwesterly for approximately 320 miles to its confluence with the Ohio River between Newport and Covington and has a drainage basin of 3,670 square miles, approximately 10% of the state (ORSANCO, 2002). From south to north, the Licking River and its tributaries flow through the following physiographic regions (Figure 2): the Eastern Coal Field, the Mississippian Plateau, the Knobs, the Outer Bluegrass and the Inner Bluegrass. In addition, the area drains portions of the Ohio River Alluvium. Although the alluvium along the Ohio River is not technically a true physiographic province, it is nevertheless an important aquifer within this region and is discussed separately. Groundwater flow in the Licking River basin varies according to the local geology. After initial runoff of precipitation, groundwater provides base flow to surface water streams, thereby sustaining stream flow during periods without rain.

Principal tributaries are the North Fork, which joins the main stem near Milford in Bracken County and the South Fork, which joins at Falmouth in Pendleton County. Other tributaries include Hinkston and Stoner Creeks, which form the South Fork at Ruddels Mill in Bourbon County and Fleming Creek. An additional 1,195 sq. miles of area draining directly to the Ohio River is included in BMU 2. Some of these more important watersheds include Kinniconick Creek, Salt Lick Branch and Gunpowder Creek. The largest impoundment in BMU 2 is Cave Run Lake, operated by the Army Corps

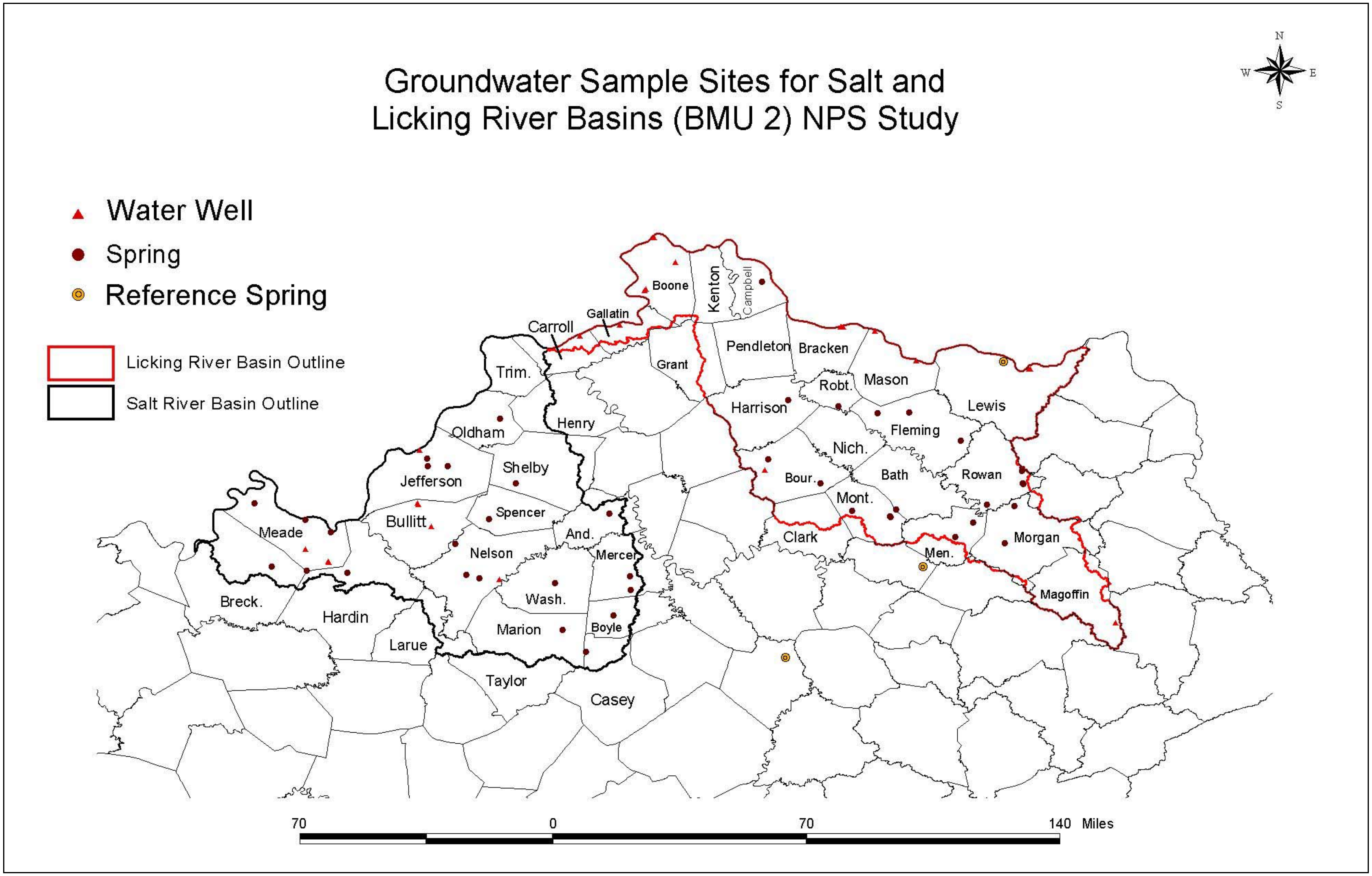

Figure 1. Salt River and Licking River basin boundaries and Groundwater Sample Sites in BMU 2

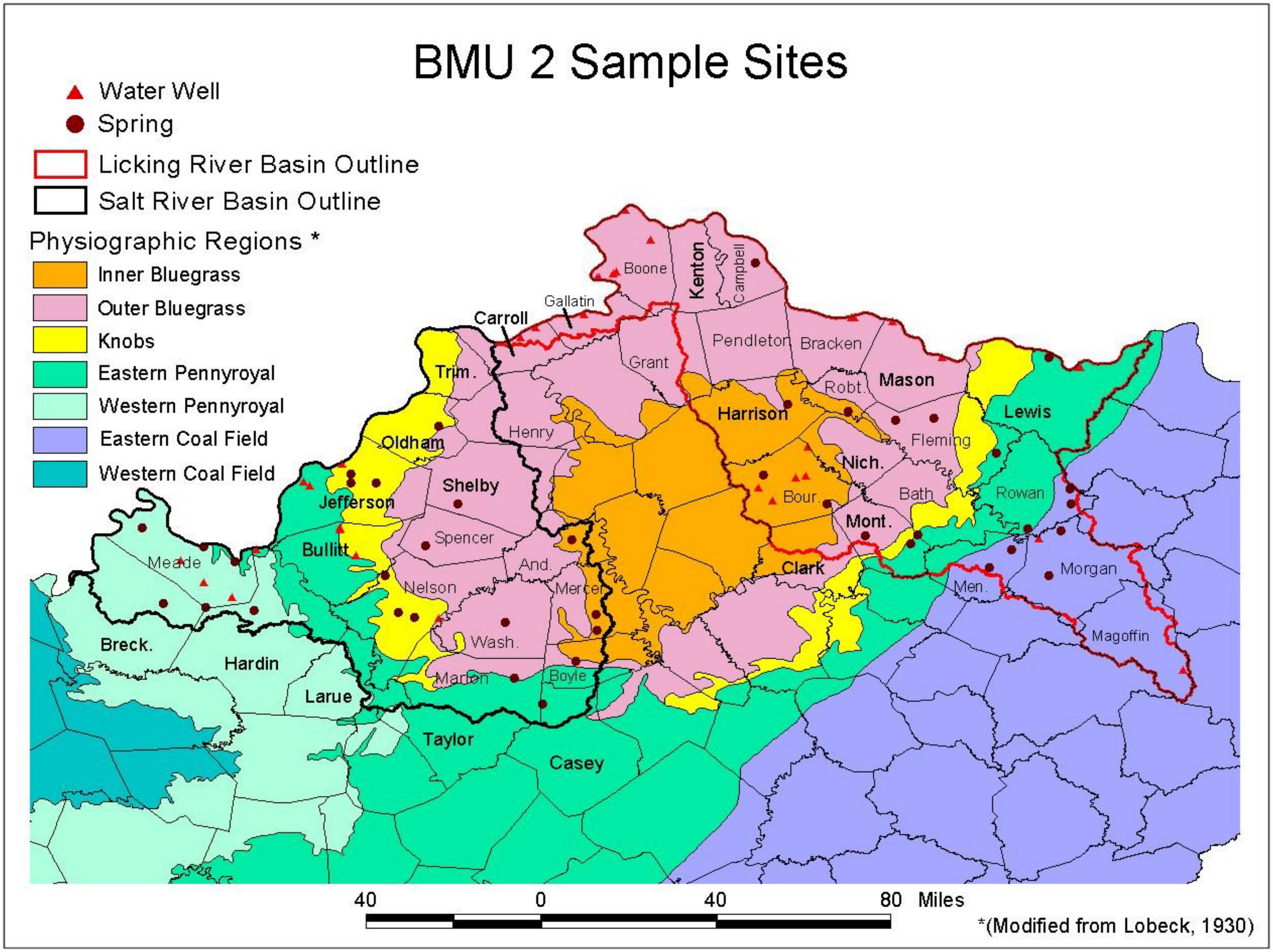

Figure 2. Physiographic Provinces

of Engineers. A dam south of Farmers in Rowan County forms Cave Run Lake, which has a summer pool of about 8,300 acres.

Salt River Basin

The Salt River rises in Boyle County and flows generally northwesterly to its confluence with the Ohio River at West Point in Hardin County. The Salt River is approximately 125 miles long and drains 2,890 square miles (ORSANCO, 2002), or about 7% of the state. The Salt River watershed drains portions of several physiographic provinces, including the Inner and Outer Bluegrass, the Knobs and the Mississippian Plateau. In the Salt River portion of BMU 2, the Ohio River Alluvium is also an important aquifer.

Groundwater flow in the Salt River basin varies according to local geology. As in the Licking River basin, after initial runoff of precipitation, groundwater provides base flow to surface water streams, thereby sustaining stream flow during periods without rain.

Principal tributaries of the Salt River include the Rolling Fork and the Chaplin Rivers. Tributaries discharging directly to the Ohio River drain an additional 1,260 square miles adjacent to the Salt River Basin proper. Larger Ohio River tributaries in this area include Sinking, Otter and Beargrass creeks. The largest impoundment in the basin is Taylorsville Lake in Spencer, Nelson and Anderson counties. The dam is located about four miles from Taylorsville and has a surface area (summer pool) of 3,050 acres.

Groundwater Sensitivity

Based upon variations in geology, topography and hydrologic regime, groundwater underlying Kentucky's various physiographic regions has varying sensitivity to contamination from activities conducted on the surface. Groundwater sensitivity to potential impacts is based upon three primary hydrologic components: recharge, flow velocity and dispersion. Sensitivity ranges from low (1) to high (5). In general, the quicker the recharge, the faster the flow and the more extensive the dispersion, the greater the sensitivity. Figure 3 illustrates generalized interpretation of groundwater sensitivity in BMU 2. Ray and others (1994) discuss this topic in detail.

In BMU 2, groundwater sensitivity ranges from high in the well-developed karst of the Mississippian Plateau and Inner Bluegrass to low in the Eastern Coal Field, Outer Bluegrass and Knobs regions.

Physiographic Provinces

Physiographic provinces (Figure 2) are differentiated on the basis of geology and hydrology and therefore the physiographic map is used as a base map to present analytical data on each parameter. Five physiographic provinces occur in BMU 2: the Eastern Coal Field, the Outer Bluegrass, the Inner Bluegrass, the Mississippian Plateau and the Ohio River Alluvium. Because each province differs in physiography and subsurface flow regime, sensitivity to contamination from nonpoint source pollution also differs. The information below is summarized from Noger (1988), McDowell (2001) and Ray and others (1994).

Generally, flat-lying Pennsylvanian-age clastic sedimentary rocks, sandstone, siltstone, shale and clay, with significant coal beds characterize the **Eastern Coal Field**, also known as the Cumberland Plateau. Erosion of this plateau has produced steeply incised, narrow valleys, with narrow ridges. Maximum local topographic relief within this portion of the study area is about 400 ft. Groundwater flow is primarily through shallow stress-relief fractures, rather than through primary porosity and permeability. Well yields are usually sufficient for domestic water supplies and range from one to several gallons per minute (gpm) when larger fractures are encountered. High-yield municipal or industrial supply wells are rare. Springs tend to have low flows and are usually perched on impermeable shales. Large-flow, base-level springs are rare. The Eastern Coal Field exhibits the lowest hydrogeologic sensitivity in the state and is rated as a "1."

The **Mississippian Plateau**, also known as the Pennyroyal or Pennyrile, is characterized by flat-lying Mississippian-age carbonate rocks, primarily limestone with some dolostone. Well-developed karst

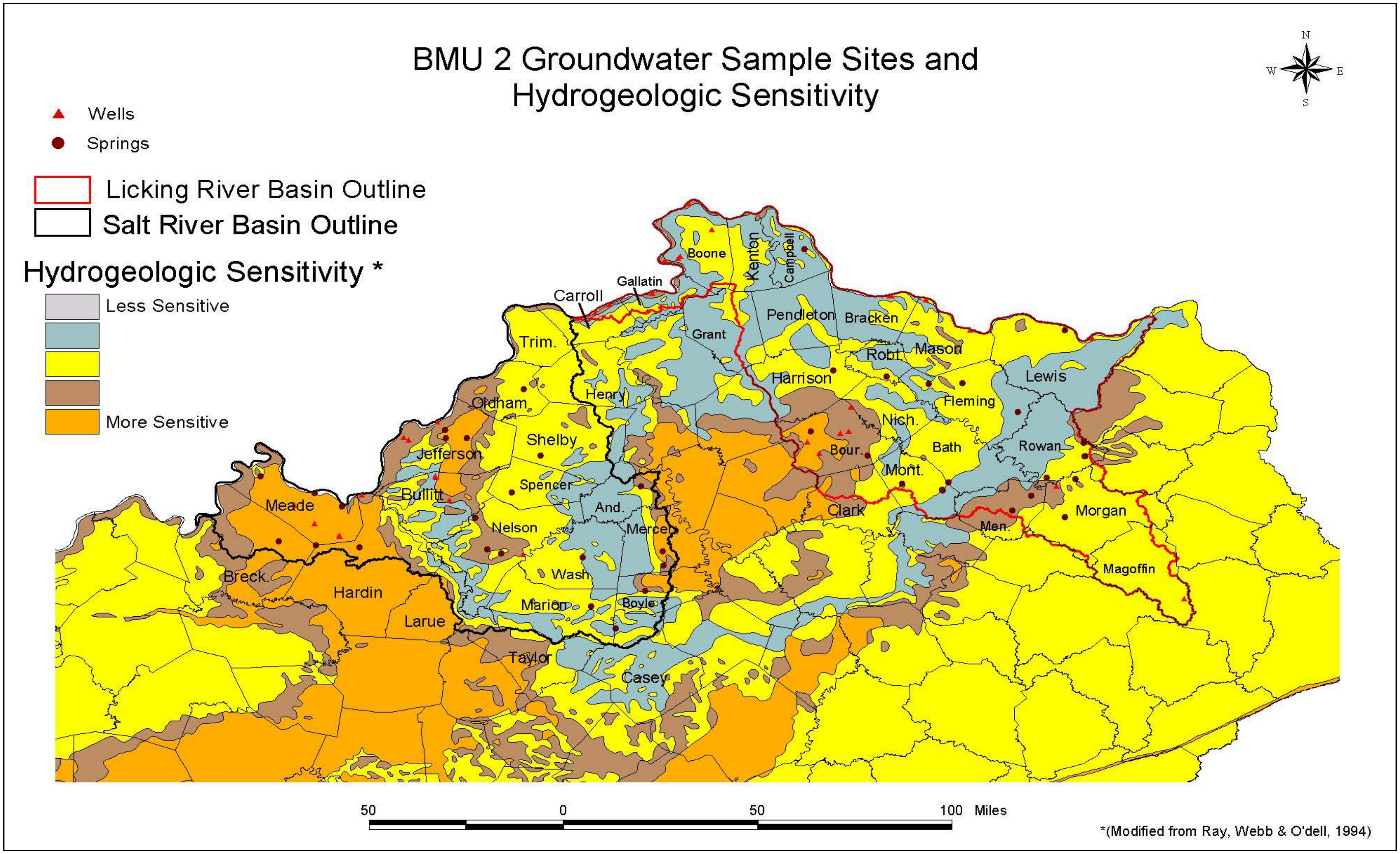

Figure 3. Monitoring sites overlain on Groundwater Sensitivity Map for Kentucky (after Ray and others, 1994)

topography occurs in this province, with an abundance of sinkholes, caves and sinking streams. Groundwater flow is primarily through solutionally enlarged conduits, but fracture flow and flow along bedding planes also occurs and can be locally important. In general, yields from wells varies widely according to the size of any enlarged water-filled conduits encountered by the well-bore and can range from less than one gallon per minute to more than one hundred. Springs developed on these thick and generally pure carbonate sedimentary rocks tend to have larger flows than other areas within the watershed, with base flow discharges ranging up to several cubic feet per second (cfs). The Mississippian Plateau is very sensitive to contamination from surface activities and rates a "5."

The **Knobs** physiographic region consists of conical hills forming a horseshoe belt almost surrounding the Bluegrass on the east, south and west. This narrow belt of hills is approximately 10 to 15 miles wide and consists of generally flat-lying sedimentary rocks of Ordovician through Mississippian age. These hills are the eroded remnants of the Pottsville Escarpment in the Licking River watershed and Muldraughs Hill in the Salt River basin. In the Knobs, resistant Mississippian-age limestone or sandstone overlies more easily eroded shale and siltstone. Knobs are generally circular in plan view and are characterized by ". . . symmetrical concave-upward slopes. . .[that]. . . steepen upward into cliffs on knobs with resistant caprocks. Knobs that have lost their protective caps have rounded crests." (McDowell, 2001). Groundwater flow in this region is primarily through stress relief fractures. Groundwater in this province is less vulnerable to surface contamination (Ray and others, 1994) and generally rates a "2." Springs in this province tend to be gravity springs, perched on stratigraphic contacts, with low and commonly intermittent flows.

Generally thin-bedded, flat-lying Ordovician and Silurian-age limestones, dolostones and shale underlie the **Outer Bluegrass** physiographic province. Because the limestone is thin and interbedded with insoluble shale, karst development is minor and local groundwater resources are limited. Groundwater flow is through poorly developed, non-integrated karst conduits and stress relief fractures. In general, Ray and others (1994) found that sensitivity in this region is low to moderate, usually rating a "2" or "3". Springs are typically low-flow (0.1 cfs or lower) and often seasonal.

The **Inner Bluegrass** is underlain predominantly by Ordovician-age limestone and shale. In general, relief is low and the area is characterized by gently rolling hills with shallow sinkholes and thick soils. Although some karst topography, such as sinkholes, caves and sinking streams, occurs in this province, most terrain is moderately dissected by surface streams. As in the Mississippian Plateau, groundwater yield is highly variable and for wells, depends on the number and size of water-filled fractures and conduits that are intersected by the well bore. Most wells yield one or more gallons per minute, which is sufficient for domestic supplies; however, large municipal or industrial wells and springs are rare. An exception to this is Royal Spring in Scott County, which supplies water to about 18,000 people in Georgetown. Ray and others (1994) assigned high to extreme sensitivity for the Inner Bluegrass province, rating it as "4" and "5."

The **Ohio River Alluvium** is comprised of unconsolidated sand, gravel, silt and clay deposits adjacent to the Ohio River. These deposits consist of Pleistocene age glacial-outwash sediments and modern alluvial sediments. Coarse sand and gravel beds in these deposits supply large volumes of water to industrial, municipal and domestic wells. Large diameter conventional wells commonly produce yields of 2000 gallons per minute and radial collector wells can produce even greater amounts of water. Because groundwater can travel quickly through these coarser sediments, Ray and others (1994) rated sensitivity as high, or "4."

In addition, some alluvium deposits thick enough to serve as viable aquifers are also present along the larger rivers in this BMU, especially on lower reaches. However, these alluvial aquifers are generally thinner and finer-grained than the Ohio River Alluvium but are nevertheless also highly sensitive to contamination. Note that although alluvial areas do not show up at the scale used for the maps in this report, these aquifers are nevertheless important along the Ohio River as well as along some other major drainages, particularly in their lower reaches.

Land Use

Land use is an important consideration regarding potential impacts to groundwater quality (Figure 4). Approximately 7% of the surface area in BMU 2 is urban, 54% is agricultural (row crop or pasture) and 39% is forest. In order to simplify the map, forest usage is combined with the relatively insignificant amount of surface area covered by wetlands, lakes and reservoirs and reclaimed strip mines. Little active coal mining has occurred the last six years in BMU 2, according to the Kentucky Department of Mines and Minerals (2002). The two primary coal-producing counties in BMU 2 are Magoffin and Morgan. Magoffin County reported two small surface-mining operations and Morgan County four (one underground and three surface) during this period. The Magoffin County mines were inactive by 1999, and neither county reported any active mining for 2001. Table 3 illustrates potential nonpoint source impacts to groundwater from varying land use.

Table 3. Land Use and Potential Nonpoint Source Contaminants

Land Use	% in BMU 2	Potential Contaminants
Agriculture, including row crop production, livestock grazing, fuel/pesticide storage	54	Pesticides, nutrients (esp. nitrate-n), salts/chloride, volatile organics, bacteria
Urban	7	Pesticides, volatile organics, chlorides
Forested, including mining, logging, silviculture	39	Metals, pesticides, nutrients, sediment, pH

Groundwater Use

Groundwater is an important resource in BMU 2, providing private and public drinking water, as well as water for industrial and agricultural purposes. Additionally, groundwater recharge provides water to maintain base flow to surface water streams after runoff from precipitation events. In BMU 2, groundwater is widely used for industrial purposes, as well as for both publicly supplied and private drinking water. Permitted industrial users and larger public water supply systems are concentrated along the Ohio River and utilize the alluvial aquifer, as shown in Figure 4. Public water systems, serving 68,713 people that use groundwater in BMU 2 are shown in Table 4. In addition, the Louisville Water

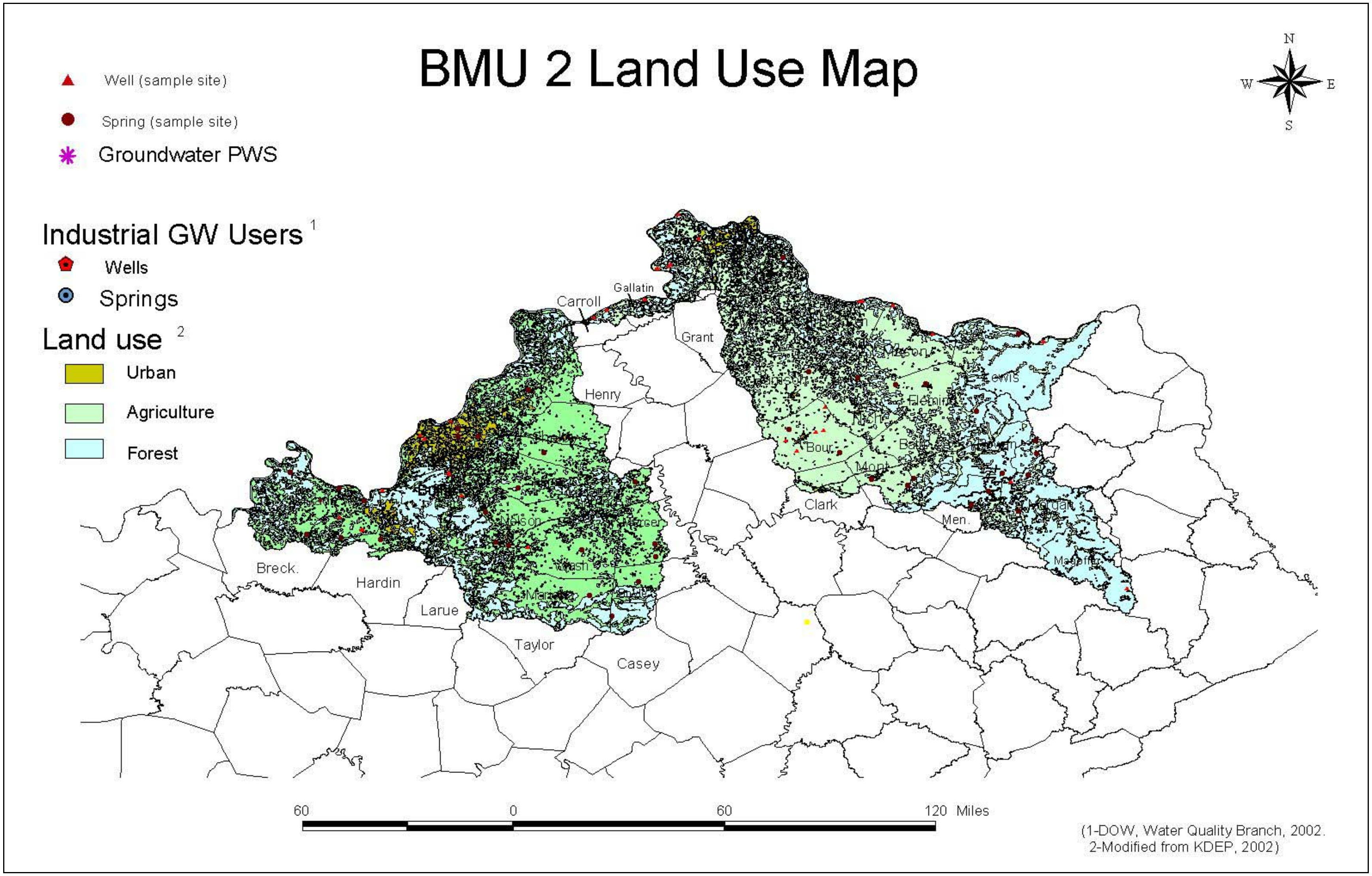

Figure 4. Land Use Map for BMU

Table 4. Public Water Systems in BMU 2 With Groundwater Source (KDOW, 2002b)

Public Water System	County	Population Served
Trapp Water Company	Boone	450
Arlinghaus Property	Boone	36
Birkle Water Supply	Boone	260
Bullitsburg Baptist Assembly	Boone	25
Camp Turnabout	Boone	429
Cincinnati Gas & Electric	Boone	150
River Ridge Park	Boone	150
Rivershore Sports Complex	Boone	25
Riverland Park	Boone	50
Kelley Elem. School	Boone	355
Potters Ranch	Boone	100
Augusta Regional WTP	Bracken	1,369
Addison Well	Breckinridge	14
Grahm Mobile Home Park	Bullitt	18
St. Anne Convent	Campbell	150
Grove Trailer Court	Campbell	12
Wren Road Campsites	Campbell	24
Thomas More College	Campbell	45
Nienaber Property	Campbell	9
H and H Farms	Campbell	15
The Roost Mobile Home Park	Campbell	23
Tiemeier Fishing Lake	Campbell	24
Doyle Club and Camp	Campbell	52
Carroll Co. WD #1	Carroll	5,085
Carrollton Utilities	Carroll	6,366
K. U. Ghent Station	Carroll	245
Dow Corning Corp.	Carroll	511
Ameriform Manufacturing	Carroll	127
Warsaw Water Works	Gallatin	2,310
River's Edge Campground	Gallatin	132
Far-Vue Farm	Gallatin	20
I 75 Campers Village	Grant	145
West Point Water Dept.	Hardin	1,200
Wallace Farm	Jefferson	50
Hosbrau Haus	Jefferson	15
Garrison/Quincy Heights WD	Lewis	2,836
Vanceburg Elec. Plant Board	Lewis	6,184
W. Lewis/Rectorville WD	Mason	4,627
W. Mason Co. WD	Mason	2,247
Brandenburg Water Works	Meade	4,214
Ekron Water System	Meade	244
Kozy Corners Trailer Park	Meade	20
Arch Chemicals	Meade	650
Salem Baptist Camp	Meade	23
Aqua Source/Goshen	Oldham	5,877
Oldham County WD	Oldham	13,860
Milton Water/Sewer Dept.	Trimble	3,630
Trimble Co. WD #1	Trimble	4,310
TOTAL		68,713

Company, which supplies drinking water to more than 750,000 people, produces 12% of its total daily production from groundwater. Groundwater from wells or springs provides private drinking water to approximately 31,350 people in the Salt River portion of BMU 2 and about 28,770 people in the Licking River portion, for a total of 61,120 (KGS, 2002). No figures are available for the agricultural use of groundwater, which does not require a permit. This use includes irrigation, livestock watering and general farm use. Although no figures are available, field observations indicate that such use is significant. Principal aquifers within the Salt and Licking River basins are shown in Table 5.

Table 5. Simplified Aquifer Characteristics in BMU 2

Geologic Age of Aquifer	**Predominant Rock Type**	**Predominant Sub-Surface Flow**	**Characteristic of Physiographic Province**
Pennsylvanian	Sandstone, siltstone, shale, coal	Fracture	Eastern Coal Field
Mississippian	Limestone, dolostone	Well-developed Conduits	Mississippian Plateau
Silurian, Devonian	Limestone, shale	Fractures, Conduits	Knobs
Ordovician	Limestone, shale	Fractures, Conduits	Bluegrass (Inner and Outer)
Quaternary	Unconsolidated Sand, silt, gravel	Granular	Ohio River Alluvium

MATERIALS and METHODS

Introduction

Parameters that are most indicative of nonpoint source pollution, as well as those parameters necessary to characterize naturally occurring groundwater chemistry and the values against which the raw data were compared, are shown in Table 1. Basic water quality chemistry can be determined from common, naturally occurring major inorganic ions, metals, residues, conductivity and pH. Parameters that are not naturally occurring are the best indicators of nonpoint source pollution and include pesticides and volatile organic compounds. Reference values used for comparison are from a variety of sources and there is no consensus regarding the appropriateness of comparing ambient groundwater with these standards. Therefore, the derivation of these standards and the applicability of them to groundwater are discussed below.

Sample results from this study were compared to a variety of existing standards, referred to as "reference values" in this report. Many of the parameters have limits established by the United States Environmental Protection Agency (U.S.EPA, 2000) for treated drinking water supplied to the public. The U.S.EPA defines three types of drinking water standards: Maximum Contaminant Levels, Secondary Drinking Water Regulations and Health Advisories:

Maximum Contaminant Level (MCL) is defined (U.S.EPA, 2000) as "the highest level of a contaminant that is allowed in drinking water." MCLs are legally enforceable limits applied to "finished" public drinking water based on various risk levels, ability to treat and other cost considerations. MCL standards are health-based and are derived from calculations based on adult life-time exposure, with drinking water as the only pathway of concern. These standards are also based upon other considerations, including the efficacy and cost of treatment.

Secondary Drinking Water Regulations (SDWR) are defined by the U.S.EPA (2000) as "non-enforceable Federal guidelines regarding cosmetic effects (such as tooth or skin discoloration) or aesthetic effects (such as taste, odor, or color) of drinking water." In common usage, this is often referred to as **S**econdary **M**aximum **C**ontaminant **L**evel (**SMCL**) and this usage has been adopted for this report.

Health Advisory (HA) is defined (U.S.EPA, 2000) as "an estimate of acceptable drinking water levels for a chemical substance based on health effects information; a Health Advisory is not a legally enforceable Federal standard, but serves as technical guidance to assist Federal, state and local officials." Again, reflecting common usage, this term has been modified slightly and is referred to in this document as the **H**ealth **A**dvisory **L**evel (**HAL**).

Many parameters discussed in this report have no MCL, SMCL, or HAL. These parameters were compared to a variety of existing standards. These include proposed, but not adopted, Department for Environmental Protection (DEP) standards for **m**ethyl ***tert***-**b**utyl **e**ther (**MTBE**), atrazine and ammonia; the Kentucky Pollutant Discharge Elimination System (KPDES) standard for total suspended solids discharged to surface waters; and the USGS-recommended surface water standard for total phosphorous.

Although established water quality standards provide a valid window through which to view the data, perhaps the most important tool is to compare data with water quality from sites known to have minimal impact from anthropogenic activities. Adopting the language used for similar surface water areas, these sites are informally called "reference springs" or "reference reach springs." Unfortunately, such sites are rare and may not truly exist, given that atmospheric deposition from automobiles, power plants and other sources, is ubiquitous throughout the Commonwealth. Reference reach springs that represent the least impacted groundwater in the state are nevertheless considered important for comparison. These sites drain forested areas unimpacted by routine surface land uses, such as recent logging, agricultural, industrial, or residential use. References springs include Cameron Spring in Lewis County (located in BMU 2) and two springs outside of this study area: Fred Mullin Spring in Rockcastle County and Nada Spring in Powell County.

Reference reach *wells* in BMU 2 are virtually non-existent, given that wells are typically installed adjacent to homes, farm areas, or businesses and therefore inherently reflect anthropogenic influences. In addition, wells in BMU 2 usually produce from shallow, unconfined aquifers. Wells completely cased through shallower aquifers and that produce from deep, confined aquifers protected from surface influences could be considered for reference purposes. However, these wells are rare in BMU 2.

Although some parameters, such as pesticides, can only come from anthropogenic sources, others, such as metals, inorganics and many organic compounds, can be both naturally occurring and from man-made sources. Therefore, reviewing land-use in conjunction with geochemical data, as well as comparing data with that from reference reach springs, can help differentiate between anthropogenic and natural sources.

Statistical and Graphical Methods

Project data were evaluated with summary statistics, summary tables, box and whisker plots, cumulative frequency curves and graduated-size maps. **Summary statistics** list simple statistics, including minimum and maximum values, median and mode. **Summary tables** list number of samples, numbers of detections and the number of detections above the particular standard of comparison for that parameter, such as MCL. **Graduated size** maps show analytical results as symbols that increase in size as values increase. These maps show the highest value for each site.

According to Hall (2002), a **box and whisker plot**, or simply "boxplot," is ". . .a graphical representation of dispersions and extreme scores. Represented in this graphic are minimum, maximum and quartile scores in the form of a box with 'whiskers.' The box includes the range of scores falling into the middle 50% of the distribution (**I**nter **Q**uartile **R**ange [IQR] = 75th percentile - 25th percentile) and the whiskers are lines extended to the minimum and maximum scores in the distribution or to the mathematically defined (+/- 1.5* **IQR**) upper and lower fences." For a full discussion of boxplots, see Appendix D.

Analyte samples for which there was no detection, based on analyte-specific testing methods and test-specific detection limits, are referred to as "censored observations" in the boxplots. A conservative approach was taken regarding these censored observations by plotting these data at their detection limit. The boxplot provides a pictorial representation of the data, showing the distribution of the data set. The censored data have values between zero and the detection limit and since the detection limit is typically low, the clustering of uncensored observations at this detection limit does not provide an unrealistic interpretation of the overall data set.

Cumulative frequency curves are graphs that show the cumulative totals of a set of values up to each of the points on the graph. The horizontal, or x-axis, shows the values for the parameter and the vertical, or y-axis, shows that percent, from 0 up to 100. Therefore, this curve represents a "running total" of the values found. Curves that are long on the horizontal axis indicate a wide range of values; conversely, frequency curves that are more nearly vertical indicate a narrow range of values.

In order to simplify the boxplots and summary tables, data for sites in the Knobs and Outer Bluegrass Physiographic Provinces are included in the Bluegrass category. The graduated size maps are overlain on a physiographic map that differentiates these provinces, so variations in the results, if any, between these similar terranes can be noted. Additionally, at the map scale used in this report the Ohio River Alluvium cannot be effectively illustrated. Therefore, care must be exercised in the interpretation of sites along the northern border of the study area. A good rule of thumb is that *wells* located on the northern edge of the area are likely in the Ohio River Alluvium, whereas springs are not.

Boxplots comparing data from the various physiographic provinces represented in BMU 2 and graduated size maps are presented and discussed in the body of this report. Cumulative frequency curves, summary statistics, summary tables and additional boxplots are presented in Appendix C.

Site Selection

The Groundwater Branch selected sites by a modified probabilistic approach in order to provide representative geographical distribution throughout the two basins. Under this approach, sites in thirty 7.5 minute quadrangles were chosen randomly for inclusion in this study. The distribution of sites selected using this method therefore provided unbiased monitoring sites representative of various land uses, each with characteristic nonpoint source threats, as well as varying aquifer types of differing inherent groundwater sensitivity. This probabilistic approach was modified because, in addition to selecting sites randomly through the use of 7.5 minute quadrangle maps, numerous other maps and data were used to facilitate site selection, including hydrologic atlases, the Division for Environmental Protection's (DEP) groundwater data base and field reconnaissance.

In general, previously sampled 7.5 minute quadrangles were omitted from this study. Public water supplies using groundwater were given preference over private supplies and unused sources. Some easily accessed springs (commonly called "roadside" springs) that are used locally for drinking water were selected for this study and are noted as "unregulated public access springs". Little information is available regarding the number of people using such springs, however, observations by DOW personnel indicate that some of these springs are used by a significant number of people. Springs were given preference over wells because generally the drainage area of a spring can be more easily determined and because of the shallow and quick-flow systems typical of springs, they are usually more susceptible than wells to nonpoint source pollution.

Because this study was designed to assess ambient groundwater conditions, those areas with known point source discharges were eliminated from consideration. For example, sites affected by leaking underground storage tanks or landfills were not sampled as part of this study. Finally, other important considerations included accessibility of the site and permission to access the site.

A unique eight-digit identification number catalogs wells and springs maintained in the DEP's database. If a well or spring selected for this study had not been assigned an eight-digit identification number, a well inspection or spring inventory form was completed and a unique identification number was assigned. The inspection or inventory form notes details of the site, including owner's name and address, location, well construction or spring development data, yield and topographic map location. The data are then entered into DEP's electronic database and forwarded to the Ground Water Data Repository at the Kentucky Geological Survey. Site locations are plotted on 7.5 minute topographic quadrangle maps maintained by the Groundwater Branch, and the forms are scanned and stored in a database as an indexed electronic image.

Sites selected specifically for this nonpoint source study, as well as other sites monitored for other programs included in the data analysis, are listed in Appendix D. Geochemical data from 80 sites were analyzed for this project. The entire study area consists of more than 9,000 square miles, or an average of one sampling site per 110 square miles. Although data are inadequate to fully characterize the groundwater geochemistry of the area, this data greatly expands the knowledge that was previously available, especially before 1995.